CHAPTER 4

COASTAL PROCESSES STUDY, SITE INVESTIGATIONS

4-1. Introduction. The coastal processes study is probably the most important part in the design of a sand bypassing project. It is virtually impossible to have a successful sand bypassing project without a good coastal processes study. A complete description of how to conduct a coastal processes study is beyond the scope of this document; therefore, this chapter will provide guidance on those aspects of a coastal processes study that are most critical to a sand bypassing operation.

a. Primary Data. For a sand bypassing project, the primary data needed from a coastal processes study are the longshore transport rates and directions and how these vary over time. Also critical are the locations of sediment deposition. The rates, directions, and locations of deposition are used to define the sediment budget for an inlet. Unfortunately, these most critical aspects of the bypassing project are the most difficult to accurately measure.

b. Site Investigations. Additional information about the site can also be very important to sand bypassing projects. While related to the coastal processes study, the site investigation will include additional items, such as social/environmental restrictions, sediment grain size distribution, topography, etc.

c. Chapter Objective. The primary objective of this chapter is to highlight sources of information and describe specific sand bypassing concerns associated with the coastal processes study and site investigation. An abbreviated example of a coastal processes study is presented in Appendix B.

Section I. Coastal Processes Study

4-2. Sediment Budget.

a. Prebypassing Sediment Budget. Preparing a sediment budget (Figure 4-1) is an important step in the design of a sand bypassing system, and probably the most important product of the coastal processes study and site investigation. A sediment budget is a volume balance representing sediment exchange for a specific section of the coast. It is based on quantifying longshore sediment transport, erosion, and accretion for a given control area. A sediment budget also includes on/offshore transport, wind-blown losses and gains, and man-made changes within the control volume, such as beach nourishment and sand mining. When performing a sediment budget, sediment sources and sinks are identified, and the amounts are determined. Results from the sediment budget calculation will determine bypassing rates, and locating sediment sinks can help to identify possible sites for bypassing. In this and the following section, the sources of information needed for the sediment budget calculations are discussed. Longshore sediment transport is the most important aspect of the sediment budget. Coastal bathymetry provides the data for erosion and accretion calculations and for wave refraction analysis. Erosion and accretion information is then used to define volume changes and to compute the amount of material trapped by inlets, completing the sediment budget. A detailed sediment budget is presented in Weggel (1981). Refer to

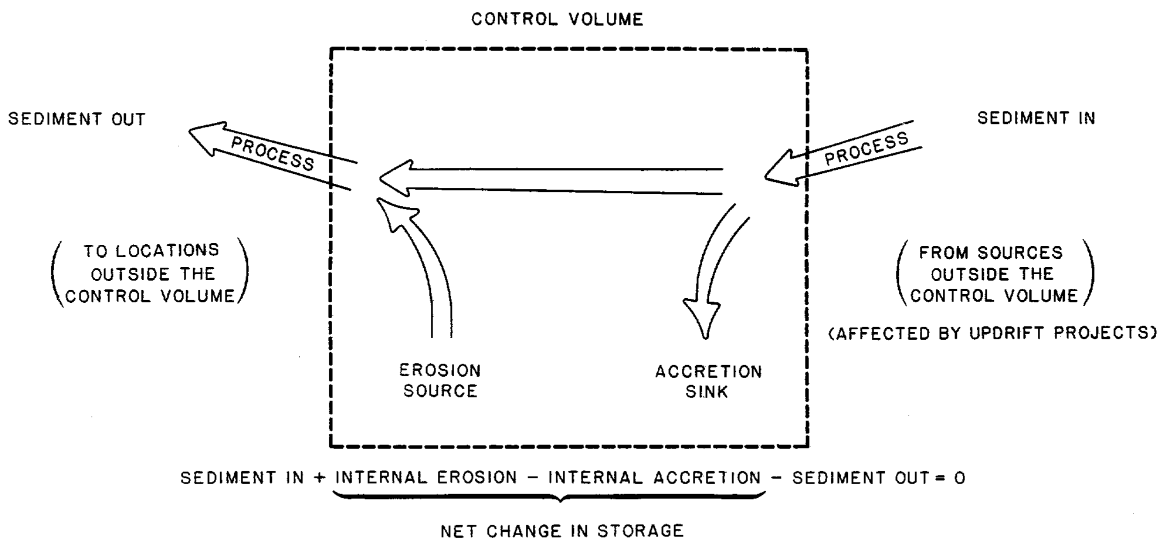

Figure 4-1. Sediment budget diagram

the SPM (1984) for details on sediment budget preparation.

b. Postbypassing Sediment Budget. To evaluate bypassing system performance, it will be necessary to compute a new sediment budget once the bypassing system is in operation. This postbypassing sediment budget should result from a continued coastal processes monitoring program. The monitoring effort should be scaled down from the coastal processes information necessary for design, but would need to include bathymetric and/or profile surveys over the bypassing site boundaries. A postbypassing sediment budget will indicate system effectiveness and help in operational adjustments, such as intake and/or discharge locations. Long-term performance of the system can be evaluated with a series of postoperation sediment budget calculations.

4-3. Sources of Information. Sources of information for various aspects of coastal processes studies are shown in Table 4-1. Chu, Lund, and Camfield (1987) also describe in detail sources of information useful for sand bypassing studies. Aerial photography is used in a number of aspects of the coastal process study and site investigation. Szuwalski (1972) describes sources and lists indexes of aerial photography prior to 1972. Other readily available sources of information such as existing Corps and university reports should always be checked.

4-4. Waves and Water Levels. Waves and water-level measurements are important in the design of sand bypassing projects. Waves constitute the primary force driving sediment transport processes. Most equations used to estimate longshore sediment transport are based on wave characteristics to some degree. Large waves can move sediment so far offshore that it is temporarily or even permanently removed from the littoral system. In addition to the cross-shore sediment transport aspects, the wave climate at a site affects the type of bypassing system as well as its location and schedule of operations. Water-level variations, both tides and storm surges, are important to the design of fixed bypassing plants.

Table 4-1

Sources of Information for Coastal Processes and Site Selection Studies

Information Needed	Sources of Information
Waves and water levels	SPM, EM 1110-2-1414 ("Water Levels and Wave Heights"), EM 1110-2-1412 ("Storm Surge Analysis"), FWGP, WIS
Longshore transport/ sediment budget	SPM, Weggel 1981, Jarrett 1977
Storm effects	Historical reports, National Hurricane Center
Social/environmental factors	Local officials, environmental specialists, EIS
Erosion/accretion data	Surveys, aerial photography, dredging records, nautical charts, beach profiles
Sediment analysis	Borings, cores, USGS reports, state geological survey reports, dredging and construction project reports
Structures	As-built plans and specs, condition reports, aerial photographs, surveys
River and stream outflows	Corps reports, USGS reports, EM 1110-2-4000 ("Reservoir Sedimentation Investigations")
Inlets	GITI reports, Corps reports, SPM, Bruun 1978, NOS charts, tidal hydraulics EM
Topography/bathymetry	USGS quad sheets, NOS smooth sheets, Corps/contractor surveys

Note: FWGP = Field Wave Gage Program Data, WIS = Wave Information Study Hindcast Data, GITI = General Investigation of Tidal Inlets Reports.

a. Cross-Shore Transport.

(1) Sediment movement normal to shore is termed cross-shore transport. Cross-shore transport is important in the design of surf zone sediment traps, both to be used for conventional dredging and fixed systems. An artificially induced underwater depression in the surf zone will receive sediments both from longshore and cross-shore transport. Contributions from both littoral transport components will need to be considered when designing traps. Several models have been developed to predict cross-shore transport, particularly to predict beach and dune response to storms. Early models, for example those by Vellinga (1983) and Kriebel and Dean (1985) provide reasonable predictions of dune retreat, but do not include building of bars and poststorm accretion. The Kriebel and Dean model is now available as part of the Automated Coastal Engineering System (ACES) (Leenknecht et al. 1990). The Coastal Engineering Research Center (CERC), US Army Engineer Waterways Experiment Station, cross-shore transport model, SBEACH, is more sophisticated, incorporating bar building, migration, and limited poststorm recovery (Larson and Kraus 1989). A personal computer (PC) version of this model should be available.

(2) At present, these models can be used to determine the potential for a surf zone trap filling resulting from cross-shore storm contributions. However, since these models do not include longshore components, they should be viewed as very conservative (i.e., they will underpredict the infilling rate). Models to predict long-term (months to years) cross-shore contributions to surf zone traps are not yet available.

b. Wave Effects on Dredges. Floating equipment, such as dredges used for bypassing, is limited by wave activity. Hydraulic pipeline dredges are the most limited. The maximum wave height in which these dredges can operate is dependent on factors such as the size of the dredge, type of pipeline used, and the anchoring system. For planning purposes, a 2- to 3-foot-high significant wave is reasonable for pipeline dredge operation. Consequently, these dredges are often limited to working in protected areas, such as between jetties or on the lee side of a jetty. They may also operate in unprotected areas during periods of low wave activity. Although operation in unprotected waters is possible, abrupt changes in wave climates may endanger personnel and damage equipment. Cases exist where pipeline dredges have sunk when subjected to changing wave conditions. Wave data can be used to help develop operational windows for open-water dredging (Figure 4-2). A significant amount of pipeline dredging along US coasts is scheduled during the summer to take advantage of the lower wave heights. Hopper dredges are less sensitive to waves, and operation in waves up to 8 feet is possible with some modern hopper dredges.

c. Wave Effects on Fixed Systems. Fixed system design considerations are somewhat different from those of dredges. For instance, they have to be constructed to withstand the design wave at their location. Interception systems have to be designed to operate under near maximum storm wave conditions. Storage systems need not be operational during maximum wave conditions, but must be designed to physically withstand maximum conditions in order to resume bypassing under average conditions.

d. Wave Effect on Timing of Bypassing Operations. Knowledge of the directional wave climate may be important for timing bypassing operations.

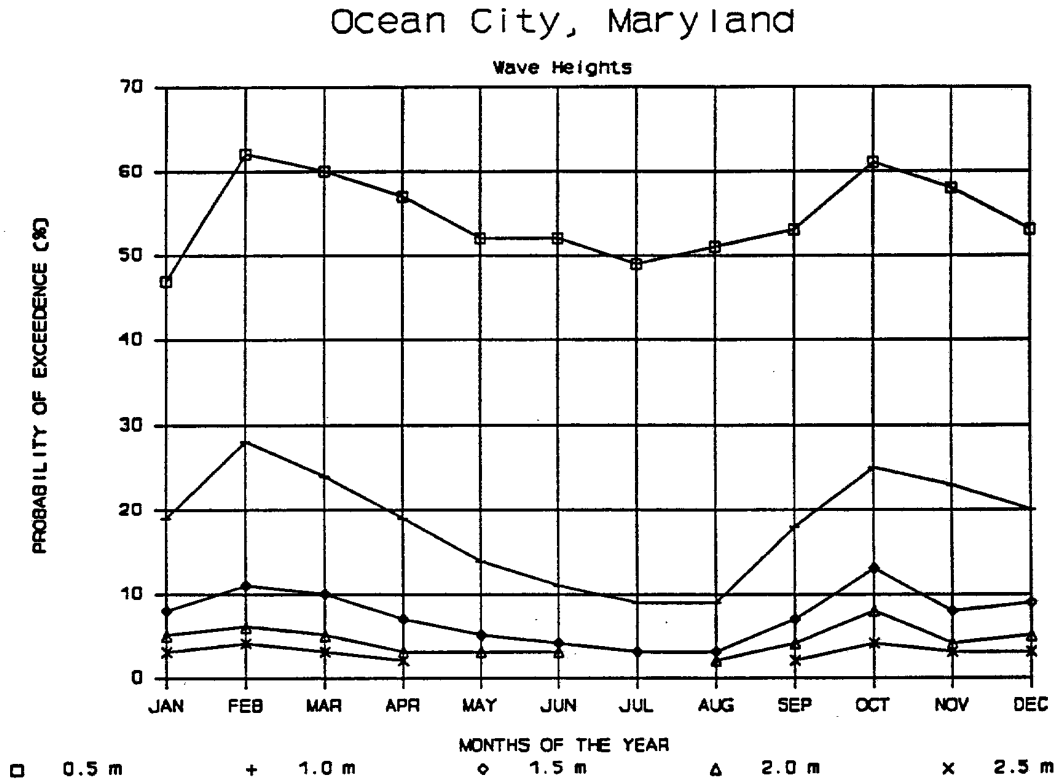

Figure 4-2. Probability of exceedance for wave heights at Ocean City, Maryland

Many locations have a change in the dominant wave direction during the year. To maximize the movement of bypassed sand to downdrift beaches and away from bypassing sites, it is preferable to bypass material just before or during the time when the waves are coming from the dominant direction. For example, on the east Florida coast, the dominant wave direction for most locations is from the northeast, with waves from the southeast occurring during the summer. Consequently, net longshore drift at most locations is to the south, and sand at inlets is bypassed in that direction. To prevent the summer waves from transporting bypassed sand back toward the inlet, sand should be bypassed at the end of August or through the fall. Then, the waves from the northeast during the fall and winter will move the sand south along the downdrift beaches and away from the inlet. Placing the sand a sufficient distance downdrift from the inlet is also important to prevent refraction effects from returning sand to the inlet. At many sites, the ebb-tidal shoal associated with the inlet will cause refraction effects that can drive sand placed immediately downdrift back towards the inlet. For effective bypassing, sand should be placed beyond the zone of significant influence of the ebb shoal and jetties.

e. Water Levels. The most common water-level variation, tide, is important to the hydraulic design of a fixed plant. Elevation of the booster pump above the water surface greatly influences the operating characteristics of the pump (Richardson and McNair 1981). The desire to keep the booster pump as close to the water surface as possible to improve performance can conflict with the requirement to have the system survive water levels associated with major storms.

4-5. Longshore Sediment Transport. Collection of available longshore sediment transport data for the problem area is extremely important. Longshore sediment transport data or computations are used to create a sediment budget. This budget is the core of a sand bypassing system design, since it describes the volume of sand and the frequency the material must be bypassed. Unfortunately, physical measurement of longshore transport is still one of the most difficult problems in coastal engineering.

a. Rates. Yearly transport rates, both gross and net, are the parameters most often available, and generally the least useful. Seasonal, monthly, daily, and extremal rates are very important in designing a sand bypassing system. Equally important are the annual and seasonal variations in anticipated rates. Obviously, short-term rates will be expected to vary greatly. The range in expected rates should be noted if at all possible. The pathways of sediment movement, especially in the vicinity of structures, is another parameter that must be described. Most important are regions where sediment movement is concentrated spatially.

b. Definitions. Littoral drift is the sediment (usually sand) moved in the littoral zone under action of waves and currents. The littoral zone extends from the shoreline to just beyond the breaker zone. The rate Q at which littoral drift is moved parallel to the shoreline is the longshore transport rate. Since this movement is parallel to the shoreline, there are two possible directions of motion, right or left, relative to an observer standing on the shore looking out to sea. Movement toward the left is indicated by the subscript lt; movement toward the observer's right is indicated by the subscript rt. In practical applications, directions of littoral drift are labeled with compass directions (e.g., north, south, etc.).

(1) Gross longshore transport rate. Gross longshore transport rate, Q_g, is the sum of the amounts of littoral drift transported to the right (Q_{rt}) and to the left (Q_{lt}) past a point on the shoreline in a given period, which produces the following equation:

$$Q_g = Q_{rt} + Q_{lt} \tag{4-1}$$

(2) Net longshore transport rate. Similarly, net longshore transport rate, Q_n, is defined as the difference between the amounts of littoral drift transported to the right and left past a point on the shoreline in a given period of time. Thus,

$$Q_n = Q_{rt} - Q_{lt} \tag{4-2}$$

The quantities Q_{rt}, Q_{lt}, Q_n, and Q_g are important in sand bypassing operations as follows: Q_g is related to shoaling rates in controlled inlets from both directions; Q_n is used to predict quantities of sand to be bypassed where there is a distinctive dominant transport direction; and Q_{rt} and Q_{lt} are used for design of jetties and impoundment basins behind jetties. In addition, Q_g provides an upper limit on the other quantities.

(3) Representations of Longshore Transport Rates. Longshore transport rates are usually given in volume per unit of time (for instance, cubic yards per year). Typical long-term net longshore transport rates for ocean-front beaches range from 100,000 to 500,000 cubic yards per year or more. These volume rates typically include about 40-percent voids and 60-percent solids, which approximate the natural porosity of sand in most coastal areas.

c. Methods. Details of the different methods for calculating potential longshore transport rates can be found in Chapter 4 of the SPM (1984). Potential longshore transport rates assume there is an unlimited sediment supply available for the waves to transport. Actual sediment transport rates can be much less if the sediment supply is limited.

d. Statistical Variations in Longshore Transport Rates. As more long-term wave data are used to calculate longshore sediment transport, it is becoming evident that the average sediment transport at a given site may be subject to wide variations. It appears that at many locations the magnitude of the gross longshore transport varies considerably over a period of 20 years or longer. At St. Mary's Entrance on the Florida-Georgia border, sediment transport calculations from WIS (Jensen 1983) hindcast data showed that gross sediment transport potential ranged from a low of 470,000 cubic yards per year to a high of 1,600,000 cubic yards per year during the period from 1956 through 1975 (Richards and Clausner 1988). Based on these data, it also appears that at many locations the yearly net drift direction can experience several reversals over a 20-year period.

(1) Sources with multiple years of data. Computing longshore sediment transport from sources with multiple years of data such as the WIS hindcast studies, Littoral Environmental Observations (LEO) (Schneider 1981), and Summary of Synoptic Meteorological Observations (SSMO) (US Naval Weather Service 1970) data has definite advantages. The variability of computed sediment transport rates becomes obvious. These sources may also allow the calculation of daily, weekly, and monthly potential rates that can be very important in the design of bypassing systems. Statistical analysis of 20 years of sediment transport calculations from WIS hindcast data at Murrells Inlet, South Carolina, showed that the standard deviation of the monthly values was greater than the average value in almost every month (Figure 4-3). In addition, as more data are analyzed, it is clear that at many locations the net longshore transport may be a small percentage of the gross longshore transport.

(2) Longshore transport from storms. Research also indicates that longshore transport may be dominated by storms and periods of high waves. Based on results from three east coast sites, the following estimates were made: 50 percent of longshore sand transport occurs during the most influential 5 percent of days; 67 percent of transport occurs during the most influential 10 percent of days; and 90 percent of transport occurs during the most influential 30 percent of days. Based on the results from seven west coast sites, it was found that 50 percent of the transport occurs on the most influential 10 percent of the days (Seymour and Castel 1985). As the wave climate changes, so will the location of the transport. During periods of smaller waves, the transport will occur closer to shore, while during storms, a majority of the transport will take place farther from shore. This concept

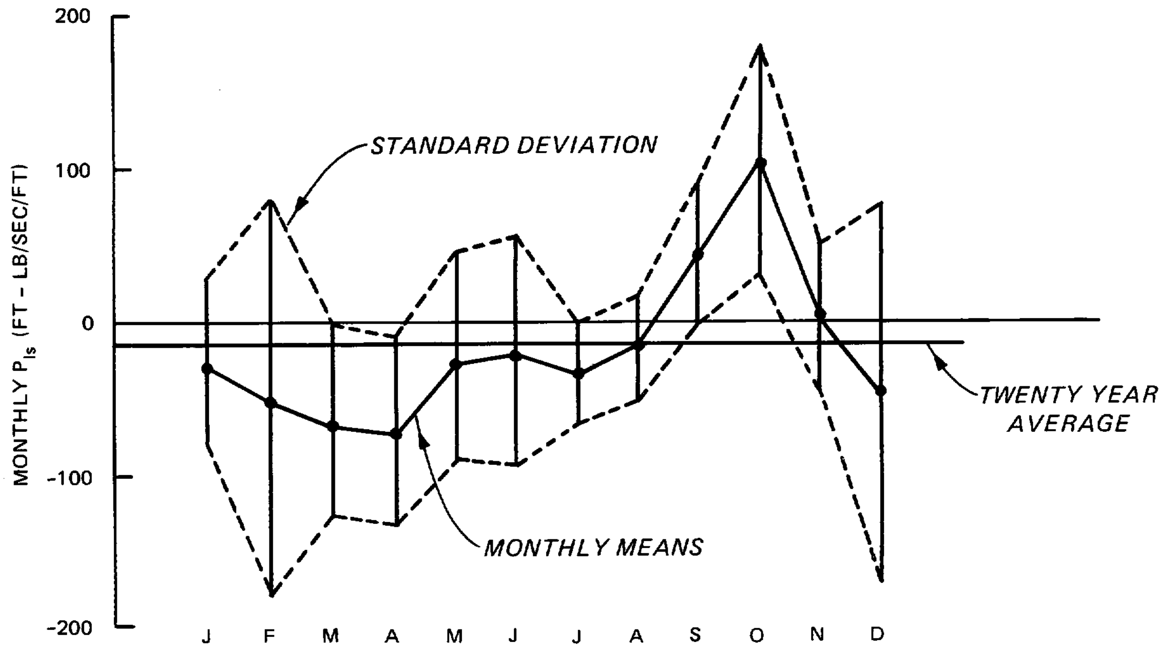

Figure 4-3. Twenty years of monthly longshore energy flux factors for Murrells Inlet, South Carolina

is important when designing an interception type system.

4-6. Cautions in Using Longshore Transport Rates. When collecting longshore transport data, it is often possible to get rates and directions indirectly from wave data as described previously. Also, for most projects, physical evidence of longshore transport rates in the form of dredging records, shoreline erosion and accretion, bathymetric changes in inlet features, etc., will also be available. While the longshore transport data created from wave data are most attractive because of the relative ease with which they can be created and manipulated in numerical models, they should be used with a great deal of caution. Longshore transport data from actual physical changes should be believed over data predicted from wave information, particularly when the physical data reflect complete sand loss or trapping. The short-term effects are often missing from physical data because data are usually not available with the required frequency. In general, it is advised to compare estimates from a number of techniques to develop a range of expected values since each method is based on different assumptions and procedures.

a. Long-Term Rates. The long-term net sediment transport direction is usually the direction in which to bypass sand. It is important to evaluate the sediment transport regime over as many years as possible, since significant reversals, even in net yearly transport, are possible at many locations. The long-term average net sediment transport rate is probably the most realistic number to relate to the average rate of sediment to be bypassed. However, the system's maximum bypassing rate should be a function of short-term transport rates for interception systems and systems with limited storage.

b. Short-Term Rates. In designing the operational mode and schedule for a bypass system (as described in Chapter 3), short-term littoral drift rates can become very important. At many sites, higher-than-average rates can be encountered, lasting from 1 day to several months. The vulnerability of a proposed system to any high short-term drift rates should be considered in system design. On rare occasions, bypassing systems have been rendered inoperable when excessive amounts of sand have blocked access to the ocean or (for jet pump systems) blocked access to the clear water supply. These situations were due to violent storms after a season with high sediment transport rates or as a result of operational problems. The ability of the system to react to higher than normal short-term transport rates should be considered from the start of the feasibility study. Pathways of sediment movement can show potential locations for the bypassing plant. Often littoral drift will interact with structures to form reasonably predictable locations from which to bypass sand.

c. Cross-Shore Distribution of Longshore Transport.

(1) An important aspect of longshore transport for sand bypassing system design is the cross-shore distribution of longshore transport. In the design of fixed plants and weir systems, knowledge of the cross-shore distribution is needed to predict what percentage of the longshore transport is available for the system to bypass. Sand is transported alongshore from the upper edge of the swash zone out to beyond the breaker line. The distribution of sediment transport across this area is not uniform and varies with tide, breaker type, bottom slope and topography (i.e. location, elevation, and number of bars), grain size, and longshore current distribution (which is also a function of many of these variables). The wide range of variables combined with the difficulty of both working in the surf zone and accurately measuring sediment transport has hindered calculation of the cross-shore distribution of longshore sediment transport. Bodge (1989) and Kraus and Horikawa (1989) summarize the available literature.

(2) Most models for predicting the cross-shore distribution of longshore transport are based on longshore current models. The majority of these models predict sediment transport maximums at somewhere between the middle of the surf zone to just inside the breaker line (Figure 4-4). Recent research has indicated that there are at least four major shapes of the cross-shore distribution of longshore transport curves (Figure 4-5) showing (Kraus and Horikawa 1989): a major peak in the outer surf zone; a bimodal distribution, within the outer surf zone and in the swash zone; one broad peak in the inner surf and swash zones; and a relatively flat distribution across the surf zone with no peak. Bodge and Dean (1987) estimate that 5 to 60 percent of longshore sediment transport occurs in the swash zone. Kraus and Dean (1987) discuss data collected with streamer traps.

(3) At present, quantitative design data to predict cross-shore transport distributions are not yet available. However, performance of existing bypassing projects indicates that substantial amounts of sediment are transported close to shore. This topic is discussed further in Chapter 6, Section II. As future information on this topic becomes available, this Engineer Manual (EM) will be updated. Prior to the updates, consult CERC for the latest information.

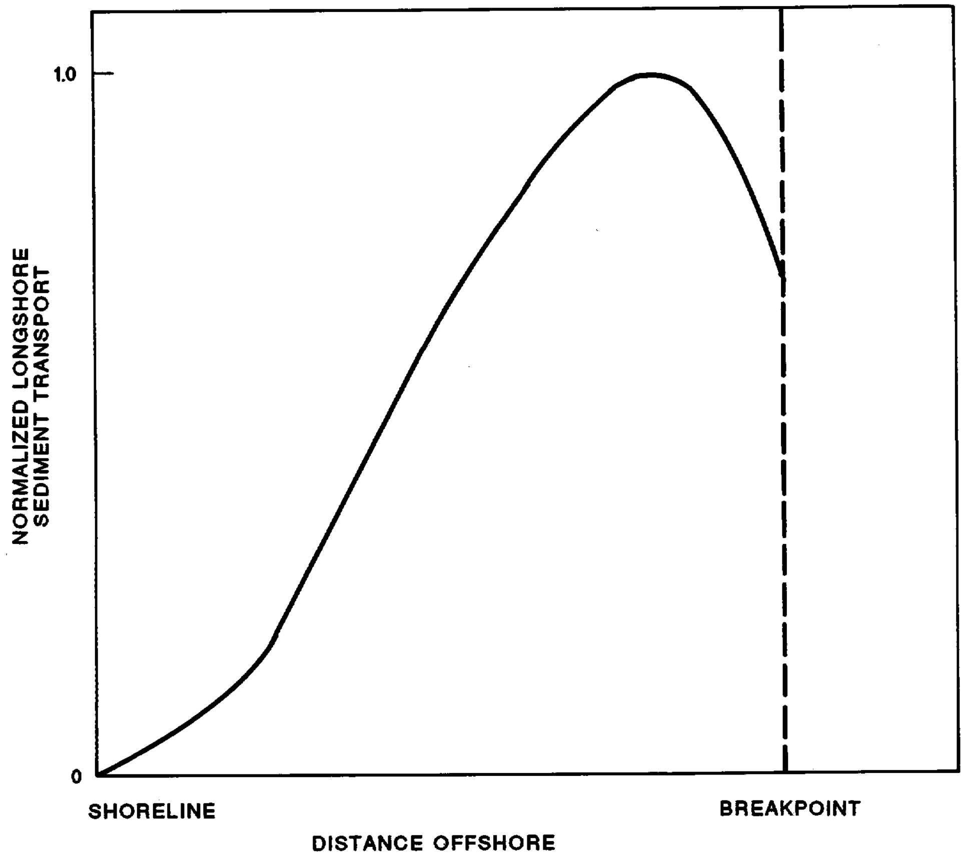

Figure 4-4. Longshore transport distribution prediced by typical longshore current model

4-7. Storms. For the purpose of characterizing a site, storms may cause two main problems: high waves resulting in operational difficulties and large sediment transport events.

a. Operational Difficulties. The potential for high waves to damage a bypassing plant is obvious. In addition to potentially damaging a fixed structure, there is also the potential to damage exposed peripheral equipment, such as booster stations and pipelines, and to uncover and damage buried pipelines. Serious problems may develop during storms for interception systems that are required to operate during such events. Power outages will stop operation of an electrically powered plant and can make operation of combustion engine-powered plants difficult. Operating personnel may not be able to reach the plant because of high wave activity or water levels. Mobile systems will need shelter during a storm. The location of such a shelter and the time required to reach it should be considered in the planning stages.

b. Sediment Transport Events. The second, and perhaps more serious, problem caused by storms is the large amount of sediment that may be moved. For fixed and semimobile systems, the possibility of becoming landlocked deserves consideration. A violent storm, such as a hurricane, may have several times the average annual gross longshore sediment transport or volume

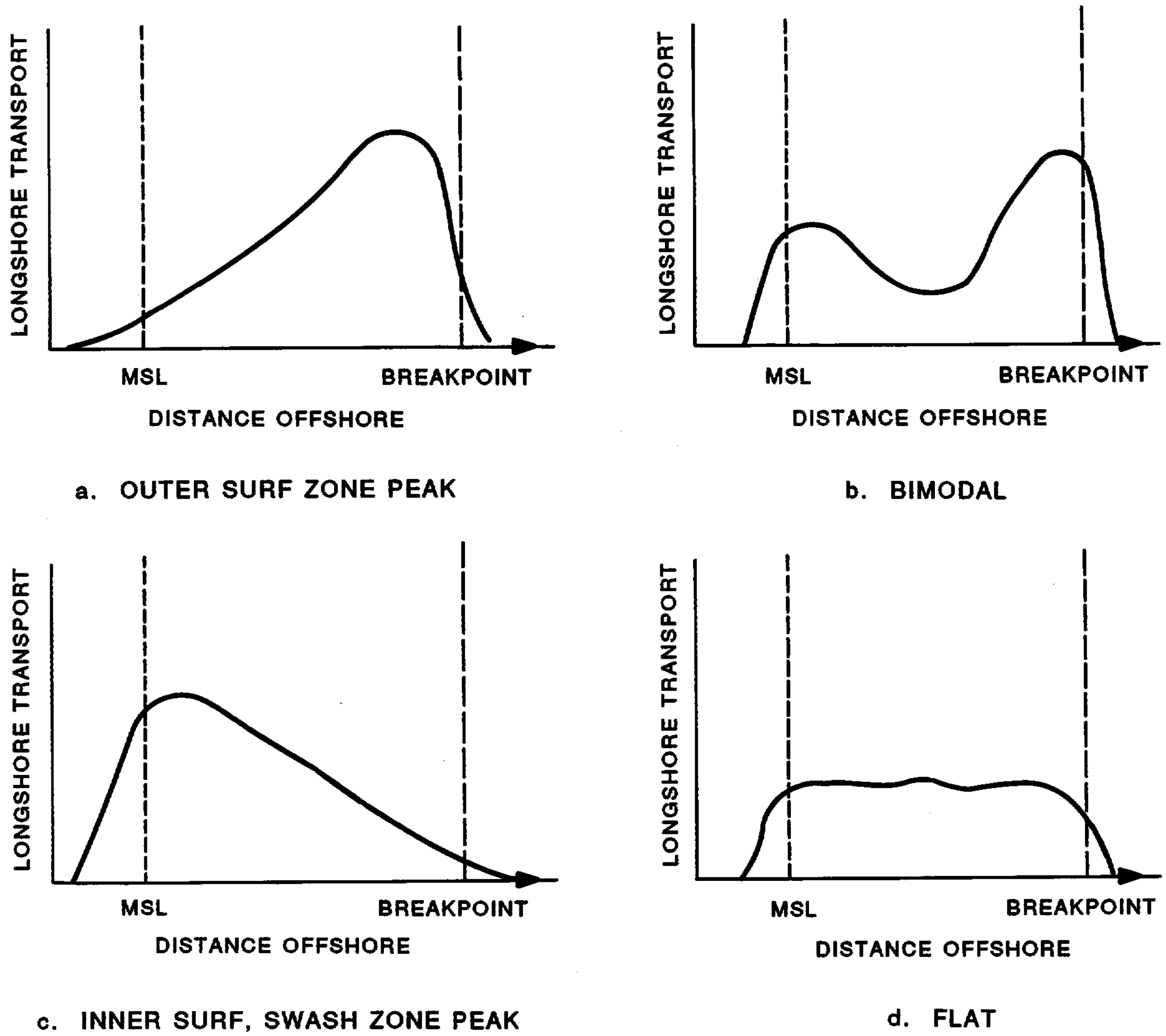

Figure 4-5. Four idealized cross-shore distributions of longshore transport

relocation within a given area. Several options are available to cope with this problem. For bypassing projects using floating plants, contingency plans should be developed for supplementing the contract to include a second dredge or a larger dredge. For fixed plants, an option is to increase the bypassing capacity of a fixed plant. This may or may not be economically feasible depending on the local probability of storms and on whether or not the system is designed to operate during storms. A second option for fixed plants would be to make contingency plans for another system such as a dredge to assist the plant after a severe storm. Another option for fixed plants or conventional dredges using a sand trap is to provide a larger storage area for sediment. Option number four would be to make the bypass intake location flexible. For example, a pumping plant or other type of system could be mounted on a trestle to provide the ability to bypass sand from points farther seaward after a storm has caused accretion. Although severe storms are infrequent at most coastal sites, the storm frequency should be determined, and large amounts of sediment influx resulting from storms should be considered when a bypass system is planned.

c. Sediment Movement Pattern Changes. A final storm effect to consider in site characterization is the possibility of the storm changing the offshore bathymetry sufficiently to change sediment movement patterns. Such changes can last from several months to several years. For example, the severe storms along the California coast during the winter of 1982 to 1983 moved sediment offshore at Oceanside, California, and created a large bar. Surveys showed that this bar then migrated in the longshore direction, which would indicate that it became a focal point for longshore transport (Waldorf, Flick, and Hicks 1983).

Section II. Site Characterization

4-8. General. The characteristics of a site have a tremendous influence in determining which type of bypassing system is ultimately selected for a particular project. A large number of factors should be considered to adequately characterize a site. Important site characteristics are described in the following sections.

4-9. Social/Environmental Factors. The ways in which site conditions can affect the design and operation of a bypassing plant are twofold: effects on local residents and tourists and effects on marine organisms.

a. Design Considerations Concerning Residents and Tourists. These types of environmental factors become more important at sites near populated areas. Noise, pollution, and the aesthetics of the bypassing operation can become major factors to be included in the total design of a bypassing system. Some of the questions that must be considered when designing a bypassing plant are as follows:

(1) Will recreational use of the beach limit bypassing during certain periods of the year (i.e. summer in the northeast and west coasts)?

(2) Will the noise associated with the bypassing system exceed local standards?

(3) Will air pollution from a diesel-powered plant create complaints?

(4) Does the system block access to portions of the sites used for recreation?

(5) Does the plant fit in with the local style of architecture?

(6) Will the pumping site conditions (e.g. jet pump crater) or discharge on the beach cause recreational and safety problems?

(7) Is there easy access to the electrical power at the site?

(8) Are easements available for the discharge line?

The above list of questions is not meant to be all inclusive but rather to serve as a general starting point from which a specific project design can be formulated.

b. Design Considerations Concerning Marine Organisms and Protected Species. Seasonal restrictions on dredging are commonly imposed by Federal, State, and local government concerning the life cycles of various marine life. Certain bypassing projects are limited to operation over the winter months. Such dredging windows may be imposed because of migrating fish, reproductive seasons for various marine life, etc. The presence of protected species on the downdrift beach can also create problems. The nesting habits of the piping plover bird may limit discharge at Indian River Inlet, Delaware. Sea turtle nesting limits sand bypassing and beach nourishment in general in Florida. Bypassing at Santa Barbara, California, is limited to the winter months between September and March because of Grunion spawning. Winter weather and its associated higher-than-average wave conditions make it more difficult to operate dredging equipment. Therefore, environmental restrictions may dictate the mode of operation (periodic or continuous) and other design parameters such as production rate, method of discharge, and even type of system.

4-10. Erosion and Accretion. Erosion and accretion data are valuable for sand bypassing projects. First, areas of erosion and accretion can help to define the region the bypassing system may influence. Second, areas of accretion are often good sources for bypassing sand. Measurements of erosion and accretion data come from periodic surveys of an area over time.

a. Measurements. Erosion and accretion data are usually associated with three locations: the beaches adjacent to the inlet or harbor; ebb, flood, and middleground shoals; and the channel.

(1) To make an accurate calculation of the volume change along a beach segment, profiles should extend from the duneline out past the limit of significant sediment transport by waves. It is important that the beach and offshore profiles be taken at the same time. Research indicates that typical errors on controlled depth sounder surveys may range from 0.3 to 0.7 foot, and these errors may not necessarily be random. General purpose depth sounder surveys typically have errors in the ±1-foot range. Figure 4-6 shows the difference in profiles taken by the Coastal Research Amphibious Buggy (CRAB) with the electronic distance measuring (EDM) station and a depth sounder survey system (Clausner, Birkemeier, and Clark 1986). The expected error volumes produced by a depth sounder survey should be considered when calculating volumes for sand bypassing purposes. Values that appear to be extremely high or low should be checked against other values in the sediment budget. Also, reducing the longshore spacing of profiles should be considered when significant differences in the profiles are evident. The chapter titled "Littoral Processes" in the SPM (1984) has additional information on profiles.

(2) Inlets can trap a significant amount of sediment from the littoral drift. Studies of several inlets on the east coast have shown they trapped up to 20 percent of the annual gross longshore transport in channels and tidal deltas. At certain locations, inlets can act as almost complete littoral sinks. For example, at St. Mary's Entrance, Florida, over 120 million cubic yards of trapped littoral material has moved seaward during the last century to form a large ebb-tidal delta. Depending on the hydraulic characteristics

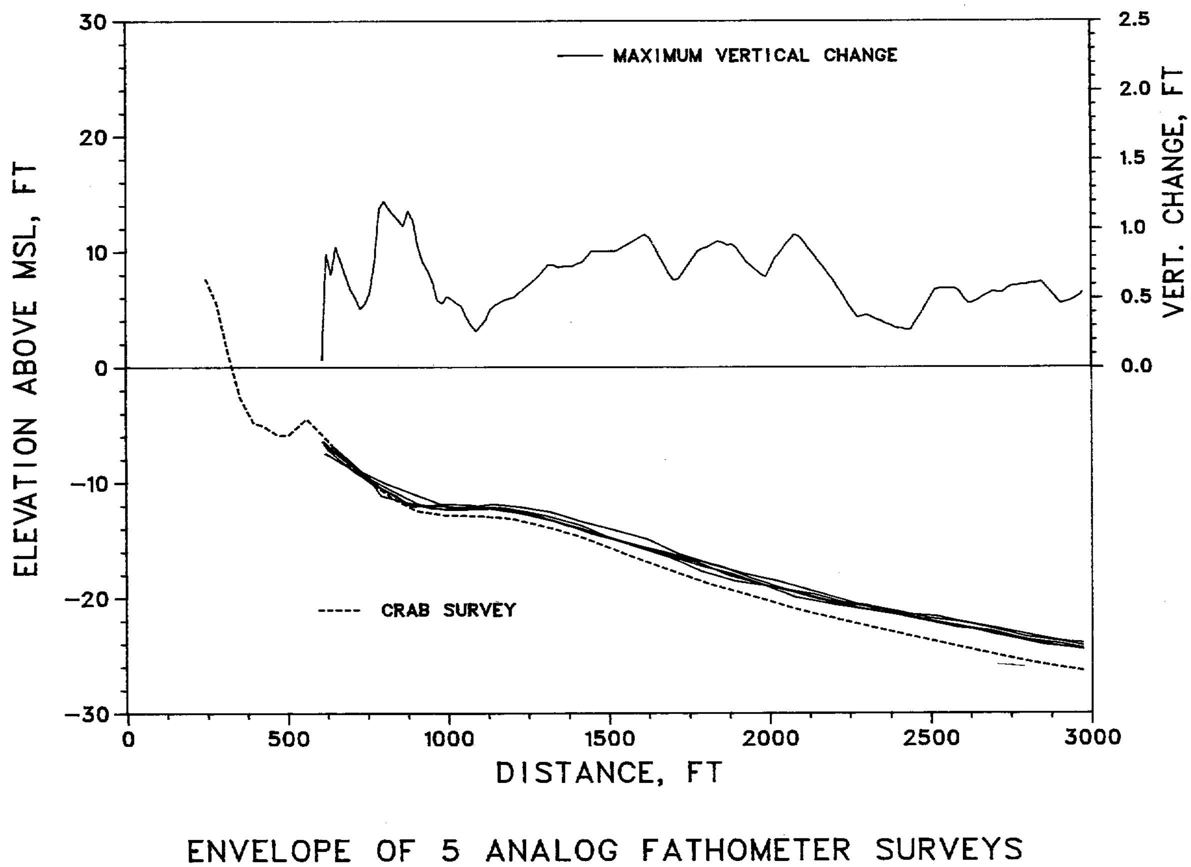

Figure 4-6. Difference in profiles at Duck, North Carolina, taken by the CRAB with EDM (dashed line) and a boat-mounted Fathometer (solid line)

of the inlet, the material can either be deposited on the ebb-tidal delta, as at St. Mary's Entrance, or remain as middleground and flood-tidal shoals. The question of using ebb-tidal deltas as a source for bypassing materials is still being debated. Present thinking is that when the bypassing amount is a small percentage of the total shoal volume, removal of this material should not cause a problem. Removal of large percentages of material for beach nourishment projects is thought to have the potential to cause a significant change in local coastal processes.

(3). Under the proper conditions, dredging records can be used to estimate gross longshore transport (Dean 1973). Trawle and Boyd (1978) provide guidance on methods for normalizing dredging volumes for different channel depths. However, a number of factors can make dredging volumes different from gross longshore transport. Channels do not always function as complete littoral traps. Shallow channels with significant currents and/or areas with a severe wave climate will allow some natural bypassing of sediment. Waves from interior sources, sloughing from the side slopes, and channel deepening effects will move sediment into a channel in addition to the longshore transport. Dredging volumes reported in annual reports should not be used to estimate bypassing quantities. Generally, these amounts are not defined as to location, time period, etc.

b. Variables. Erosion and accretion variables include the areas involved, annual and short-term rates, historical trends and changes, and the pathways of movement. The area involved should be defined as accurately as possible. The limits of the erosion/accretion area will help to describe coastal processes and provide valuable clues as to the type of sand bypassing system needed. Annual and short-term erosion/accretion rates are used to define the problem and to help the coastal engineer in predicting what effect the bypassing system may have on the shoreline. Detailed shoreline change information for some portions of the US coast can be found in shoreline movement reports (e.g. Everts, Battley, and Gibson 1983) that discuss shoreline movement rates, areas of erosion/accretion, and historical trends.

(1) Analogous to the definition of littoral drift pathways, determining the fate of eroded or accreted material is also extremely valuable. Some material may be added or lost to the longshore sediment process, whereas other material may move on- or offshore. An accurate determination of these movement pathways can be used to enhance the capabilities of a proposed sand bypassing system.

(2) Areas of accretion within a site are primary potential locations for bypassing systems. Often these locations are the direct result of man-made structures, such as jetties and breakwaters, constructed to aid navigation at an inlet. The average amount of sediment to be bypassed over the long term depends on the primary purpose of the bypassing project. When maintenance of the navigation channel is the main concern, the average shoaling rate in the channel is the amount that needs to be bypassed. For maintenance of eroding downdrift beaches, the erosion rate of the beaches is the amount that needs to be bypassed. The amount of sediment bypassed does not necessarily equal the amount that remains on the beach. In some cases, sorting losses will require a greater volume of sand bypassed to result in the desired amount of sand remaining on the beach. The amount of material to be bypassed will directly affect the size of the bypassing plant and the frequency at which it needs to operate to bypass the required amount of material.

c. Methods. One method of determining erosion and accretion volumes is through successive channel surveys, which can also detail pathways of sediment movement and provide valuable insight into local coastal processes. This method of analysis was used at Oceanside Harbor, California. Successive harbor surveys revealed that even though the net littoral drift was from the north, the majority of the harbor shoaling came from the south during reversals in the sediment transport direction (Figure 4-7).

4-11. Sediment Analysis. The grain sizes of sediments at the site have a significant effect on the bypassing system's efficiency and operation. The two primary factors to consider are matching the grain sizes of the bypassed material with the downdrift beach and calculating the pumping requirements for pipeline-based systems.

a. Bypassed Material Grain Size. For those bypassing operations where the location of the material to be bypassed is fixed (for example, a channel shoal or impoundment basin), grain size will not influence site location. However, for sites where there is some choice in where to bypass from, the

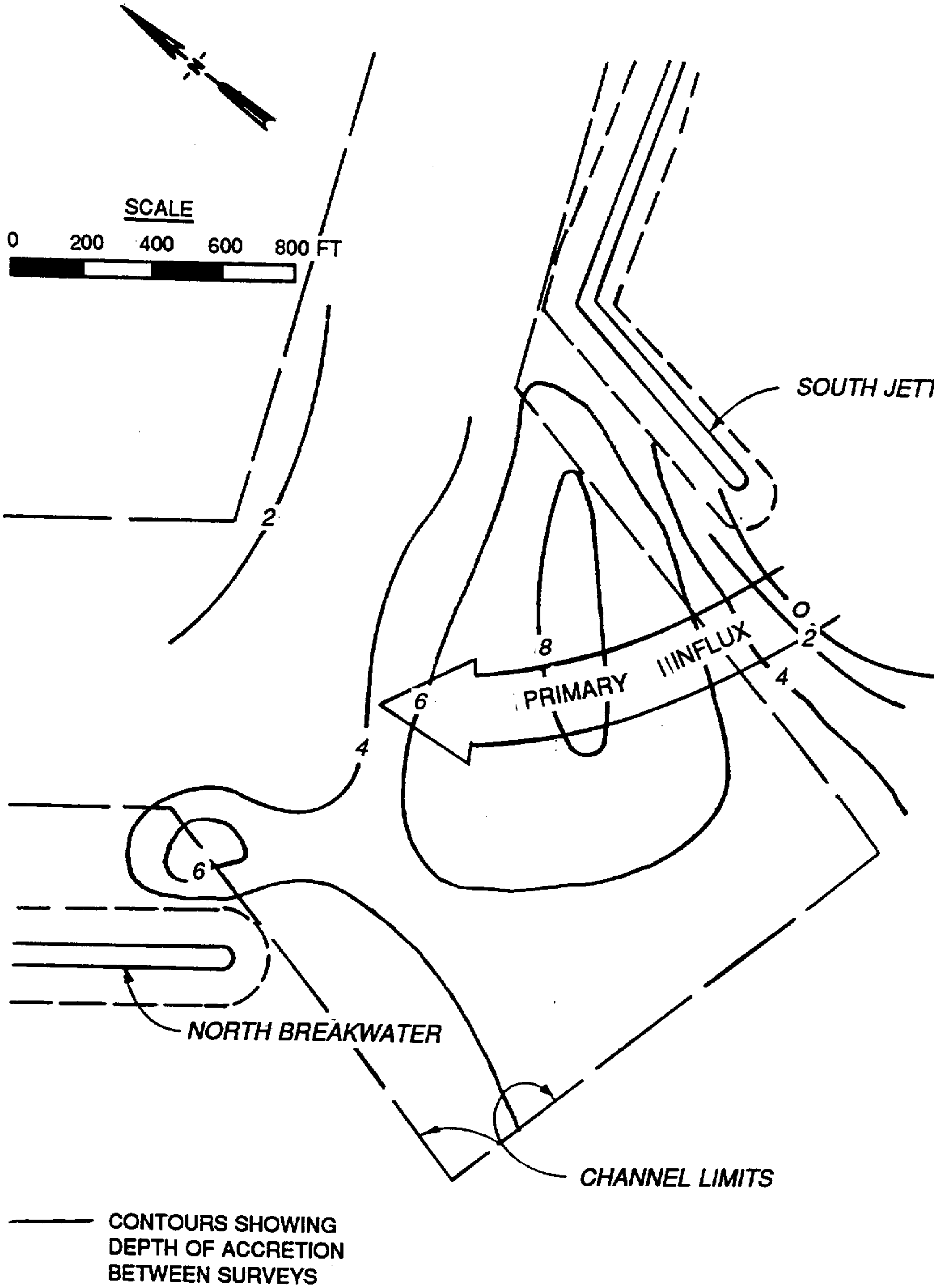

Figure 4-7. Sediment movement at Oceansde Harbor, California, between July 1973 and February 1974

grain size at each potential bypassing location can be a factor. For most sand bypassing operations, it is desirable to place the bypassed material on eroding downdrift beaches. Beach nourishment of this type is more successful when the bypassed sand grain size is comparable to or larger than that on the native beach. Chapter 5 of the SPM (1984) provides guidance for determining the compatibility of native and borrow sediments.

b. Pumping Characteristics. Sediment characteristics can also affect pumping characteristics for systems that move bypassed sand hydraulically. As grain size increases, friction losses in the pipeline increase, thereby raising the amount of power required to pump material a certain distance. For long discharge distances, one or more booster pumps may be needed in the discharge line, raising both capital and operating costs and making system operation more complex. Figure 4-8 provides an example of how grain size can affect booster pump spacing. Many qualifications and assumptions are associated with this figure; therefore, it is intended only as an example illustrating a trend.

c. Other Sediment Characteristics. In addition to the grain size, several other sediment characteristics of the site should be considered as they might apply to bypassing. The presence of fine-grained material or cementing agents can seriously affect excavation and/or pumping efficiency. Also, large objects such as cobbles, shells, or debris can cause many types of operational difficulties, depending upon the type of bypassing system. Fixed plants are particularly susceptible to debris problems since they bypass from

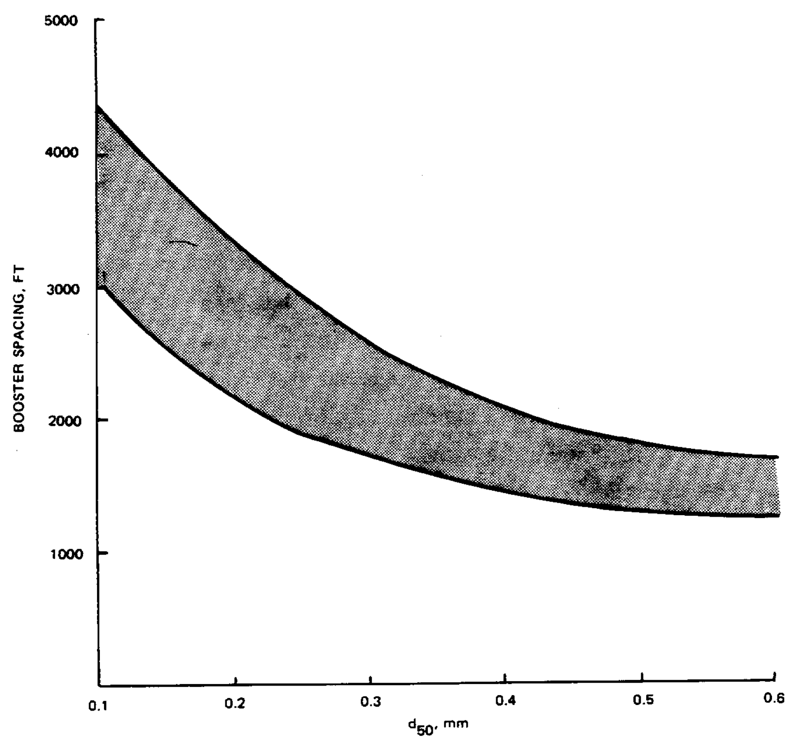

Figure 4-8. Booster station spacing increases as sediment size decreases

a single point, allowing debris to concentrate at that location. Sediment characteristics must be determined before designing a bypassing system.

d. Information Required. Sediment parameters that should be quantified include grain size distributions, composition types, and variability of each by regions (i.e. onshore, offshore, channel, accretion fillet, etc.). Temporal variability may also be a significant factor when large seasonal variations occur or when the area is accreting or eroding. Caution should be exercised when too few samples are available. Serious consequences may result when design conclusions are based on only one or two grain size distributions taken in the general area of interest. Core samples should also be available to provide information on subsurface features and compositions.

4-12. Structures.

a. Deposition patterns around structures will often produce good locations from which to bypass material. While the patterns are not universal and should be checked on existing structures, they can be estimated from past experience and model studies. Figures 3-8 through 3-12 (Chapter 3, Section III) show probable areas of accretion around structures that could be sites for bypassing. Care must be exercised in designing a bypassing system for use on or near a structure. For fixed bypassing plants placed on a structure, the additional foundation loading should be taken into account. The location of material removed near a structure has to be planned so as not to undermine the structure foundation or cause a slope stability problem.

b. The pertinent information on structures in the problem area includes types and purposes, time-history of construction (especially for portions built at different times), and present conditions. As-built plans and specifications will detail their construction. The structures’ effect on the coastal processes may have a large impact in defining the problem area and in determining feasible solutions. For example, Figure 4-9 shows paths of diment transport predicted by model studies of Oceanside, California (Curren and Chatham 1980), used in the design of the experimental Oceanside Sand Bypassing System (Appendix E).

4-13. River and Stream Outflows. The information needed to evaluate river and stream outflows include sediment discharge quantities, water discharge quantities, and the variability of each. Sediment discharge volumes are important to sand bypassing because the amounts may be a significant portion of the sediment budget in certain locations. The grain size of the river-discharged sediment during a flood may be different from that of normal longshore transport and may cause pumping problems. Also, floods may prevent operating personnel from reaching the bypassing plant, and the debris carried by floodwaters may damage bypassing plant equipment or clog intakes. Rivers do not supply sand directly to most segments of the east and gulf coasts. However, on some of the west coast and some parts of the Great Lakes, sand carried to the coast by rivers may be a significant source of littoral materials.

4-14. Inlets. Many sand bypassing operations are needed because of inlet effects on the surrounding coastline, and most sand bypassing plants operate in or adjacent to an inlet. Consequently, knowledge of inlet characteristics is required for the design of a sand bypassing system. Inlet migration

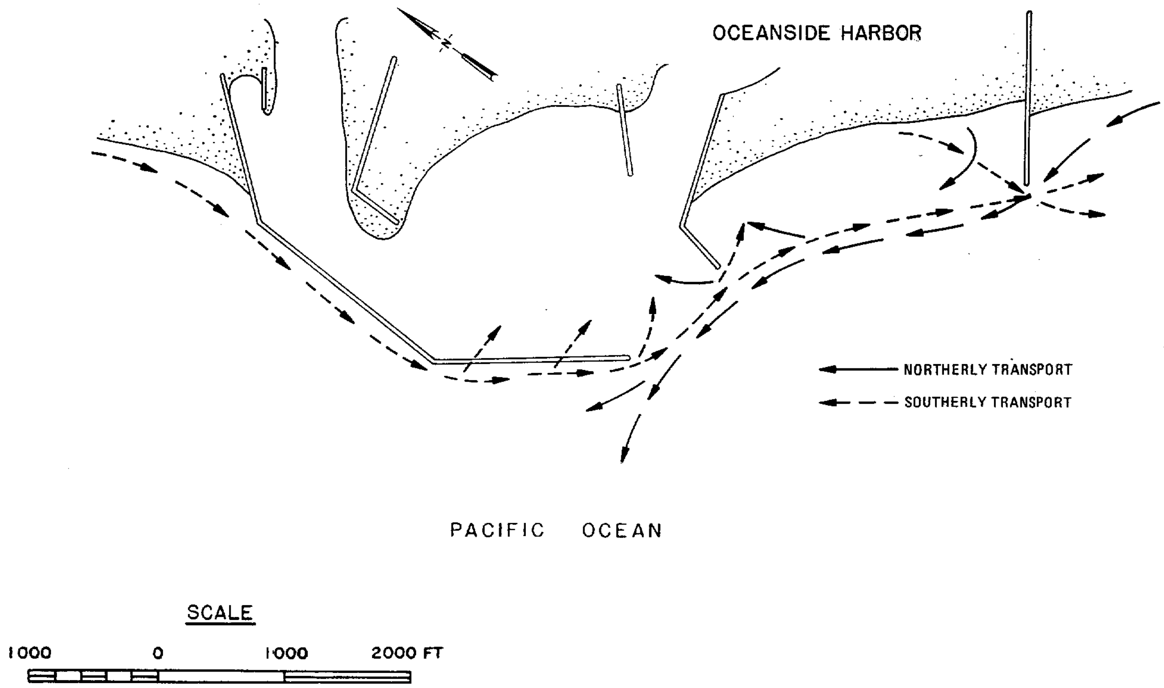

Figure 4-9. Sediment transport paths as predicted by model studies at Oceanside, California

tendencies should be investigated (Figure 4-10) (Everts, Battley, and Gibson 1983). Efforts should be made to determine the location, size, and historical and seasonal changes of the bars, or ebb- and flood-tidal deltas, associated with an inlet. Sometimes these bars can be used as sources for bypassing material, and the effects of bypassing on the size and location of the bars must be considered. Velocities and flow patterns of ebb- and flood-tidal currents are needed to design features such as deposition basins and to determine bypass plant operating conditions and time bypassing operations.

a. Channel Migration. Channel migration tendencies should be included as a part of site characterization. Changes in the length, orientation, or permeability of jetties and breakwaters, the addition of weir sections, and other local changes to the sand supply or inlet hydraulics can cause rapid changes in the channel alignment and position between the controlling structures. Masonboro Inlet, North Carolina, is an example of this phenomenon. Figure 4-11 (Kieslich 1981) shows changes in the thalweg of Masonboro Inlet after the jetty was constructed. Change in position of the channel thalweg can cause several problems. Cross-channel pipelines may be exposed, bridge piers may be undermined, and the location and effectiveness of deposition basins may be adversely impacted. Tidal current patterns and velocities associated with inlets are a part of site characterization. Current patterns can show locations where sediment may be deposited. Current velocities may adversely affect operations with floating plants and have the potential to scour around intake and discharge pipelines.

b. Existing Data. In addition to Corps reports, the GITI reports have extensive information on inlets. The 22-report series is divided into three

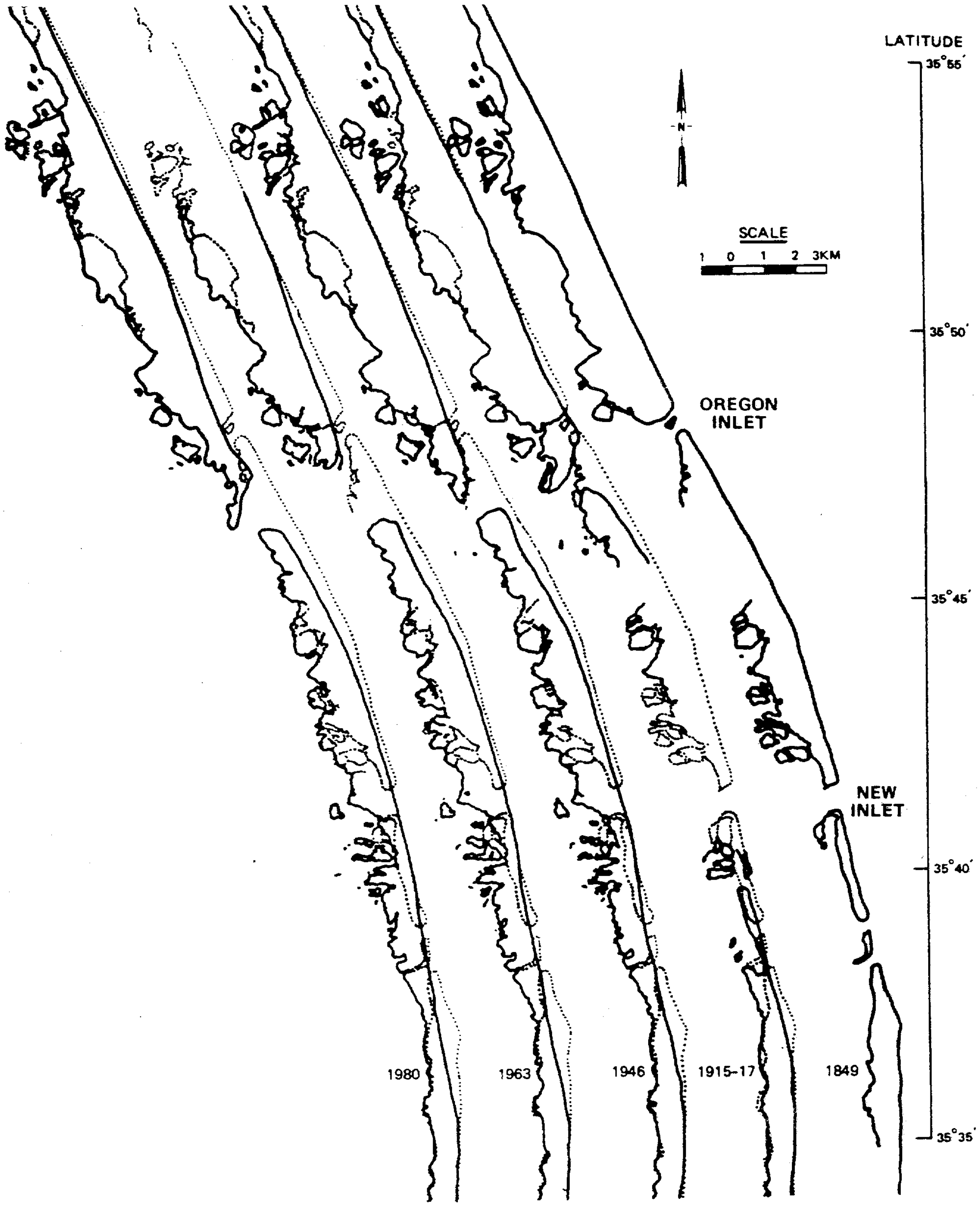

Figure 4-10. Changes in ocean and sound shorelines adjacent to Oregon Inlet, North Carolina, for five surveys between 1852 to 1980

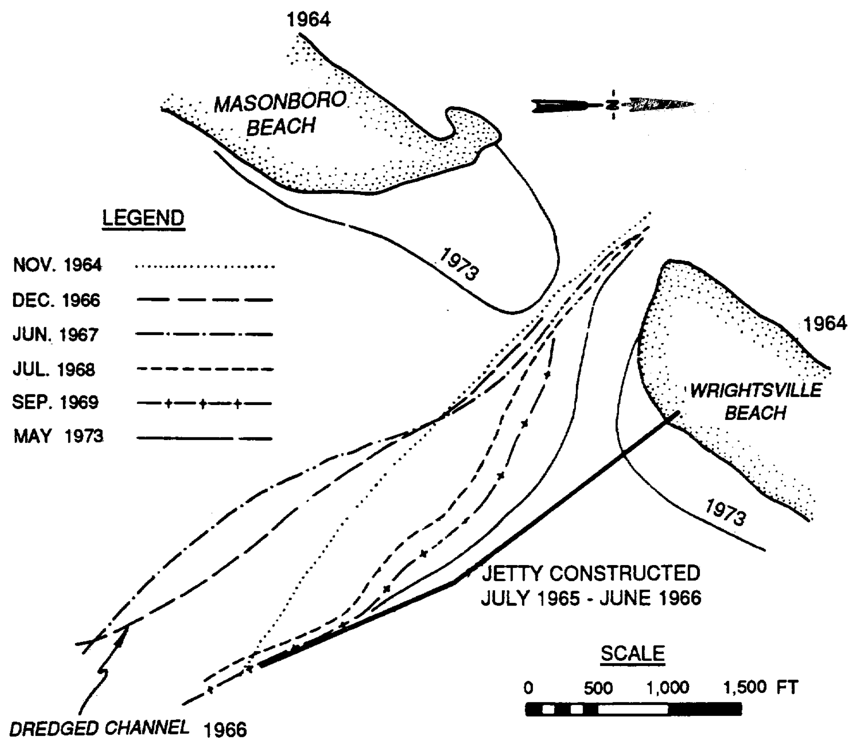

Figure 4-11. Time-history of channel thalwegs, Masonboro Inlet, North Carolina, November 1964 to May 1973

study areas: inlet classification, inlet hydraulics, and inlet dynamics. For sand bypassing system design, the most useful reports are numbers 5 (Barwis 1976) and 19 (Kieslich 1981). The geomorphology (study of surface relief features) of tidal inlets is well documented. In addition to the summary in the SPM (1984), reports by Nummedal et al. (1978), Fitzgerald and Fitzgerald (1978), Boothroyd (1978) and Fitzgerald (1982) provide a good background on geomorphic processes occurring at tidal inlets.

4-15. Coastal Bathymetry and Topography. Though identical except for the location of the measurement, bathymetry and topography have different applications for sand bypassing. Bathymetry is used for volume computation in erosion/accretion, refraction analysis, and storm surge calculations. Topography is used to determine site access and flooding potential. Beach profiles combine topography and bathymetry and may be classified in either category.

a. Coastal Bathymetry. Changes in coastal bathymetry over time provide the volume change information needed for calculation of erosion and accretion rates. (This information is crucial for calculating sediment budgets.) Computer programs are available to perform these calculations from digitized bathymetry. Refraction analysis is used to compute nearshore wave height and direction. This information can be used to site a sand bypassing operation and to compute sediment transport rates. Storm surge calculations require the same type of bathymetric data as for refraction analyses; however, the grid size is often larger. Computer models used for refraction and storm surge are constantly being developed and updated. Check with CERC for recommendations on which model to use. The Coastal Modeling System (CMS) instruction manual (Mark, in preparation) has the latest information.

b. Topography. Topography is the final part of site characterization. Access to the site is required during construction when the selected sand bypassing system incorporates additional structural features. For example, a fixed plant will need heavy construction equipment such as trucks and cranes at the site. Although this kind of construction can be done from the water, it is generally much easier and less expensive to accomplish the work from land. Topography at the site should be examined to determine if the existing roads are suitable. If roads do not exist, it must be determined whether they can be constructed at a reasonable cost. Topography is also a factor in the routing and construction of discharge pipelines. Typically these pipelines are 0.5 to 2 miles long. The elevation along the route and obstacles such as river crossings can constitute significant impacts on portions of a pipeline design and affect the hydraulics of the entire sand bypassing system.